International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN (P): 2249-6890; ISSN (E): 2249-8001
Vol. 9, Issue 4, Aug 2019, 479-488

WEAR CHARACTERISTICS OF Al 6061-TiB_2 METAL MATRIX COMPOSITE DEVELOPED BY IN-SITU TECHNIQUE

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ABSTRACT

Metal Matrix Composites (MMCs) are extensively used in structural, automobiles and aerospace employments because of their enhanced mechanical characteristics. Wear tests are essential to study the performance level of MMCs used in various engineering applications. The joined special property of stir casting and in-situ system shaped Al6061-TiB_2 composites, with dissimilar reaction holding periods from 0 to 60 minutes in steps of 15 minutes. Wear tests have been carried out to find the wear characteristics of both, the matrix alloy Al 6061 and the composites produced by the introduction of the reinforcement phase, and TiB_2 using the in-situ method by adding halide salts K_2TiF_6 and KBF_4 in to the liquefied state at 850 ℃ with dissimilar reaction holding periods. Pin-on-disc device have been used for the testing purpose under different applied loads with different reaction holding times. The results show that the rate of wear of all composites is lesser than that of the matrix amalgam. The incorporation carried out by TiB_2 in Al6061 alloy improves the wear characteristics.

KEYWORDS: Metal Matrix Composites (MMCs), Al6061-TiB_2, K_2TiF_6 and KBF_4, Pin-on-Disc Apparatus & Reaction Holding Times (RHTs)

Received: Apr 22, 2019; **Accepted**: May 13, 2019; **Published**: Jul 03, 2019; **Paper Id.**: IJMPERDAUG201947

Original Article

INTRODUCTION

In this industrial era, aluminium centred particulate fortified metal matrix composites have evolved as a significant class of better performance materials for their dominant usage in chemical, locomotive, aerospace and automobile industries. This dominant usage is because of their prominent characteristics like high elastic modulus, enhanced strength and improved wear resistance unlike primitive base alloys. In recent times, *in-situ* methods have been established to manufacture aluminium centred metal matrix composites [1-7], which can last long to enhance adhesion at the conjoin, resulting in improved mechanical characteristics. In-situ amalgams are multi-phase ingredients, where the reinforcing phase is manufactured inside the matrix, through out the composite formation.

Presently, there are diverse ways to manufacture Al-TiB_2 mixtures. But in-situ method is attaining prominence, because of the easiness of its construction. Robust attachment of TiB_2 by Al amalgam matrix has remained and proved to be the regulating feature that disturbs the improvement of wear resistance of the amalgams. Information on in-situ handling of these amalgams is nominal [4-7]. Augmented consideration has remained to emphasize the direction of particulate reinforced metallic matrix compound for tribological solicitation owing to the benefit of MMCs, for instance worthy sliding resistance, great load handling capability and small concentration. MMCs comprising a small portion of nitride, carbide and oxide elements are commonly the selected

composites for presentation that needs worthy wear resistance.

In the midst of various reinforcements, TiB_2 has appeared to bea capable aspirant for aluminium centred mixtures. That is because of the point that TiB_2 is rigid, firm and added significantly to ensure not to respond with aluminium to form reaction element at the connection of reinforcement and matrix. $TiB_2$is an obstinate material that displays exceptional structures, for instance, higher melting point (2790°C), higher hardness (960 HV or86 HRA) and higher modulus features. Its confrontation to plastic distortion at high temperature depicts to designate a worthy and prospective reinforcing applicant in an aluminium matrix.

Restricted amount of published work is accessible on the sliding wear performance of amalgams through TiB_2 as reinforcement substance formed by in-situ [7-10]. Mandel et al [3] in their research on the sliding wear of Al-4Cu-TiB_2 in-situ amalgams indicated that, TiB_2 elements evidently enhanced the wear characteristics of Al-4Cu amalgam. Roy et al [11] have associated wear opposition of aluminium reinforced with TiB_2, TiC, SiC amalgamated by precipitate metallurgy direction. It was specified that, TiB_2 exhibited improved wear resistance than further dispersoids.

Manufacture of in-situ amalgams embraces amalgamation of the reinforcing phases straight through the matrix. This method is in divergence with ex-situ mixtures, where the reinforcements are amalgamated distinctly, and then familiarized in to the matrix through a subordinate method such as melting, subversion or precipitate handling. By means of the in-situ MMCs, approach by extensive choice of matrix constituents (Fe, Pb, Cu, Al, Ti and Ni) and next phase elements (borides, nitrides, oxides and carbides) can be formed [12].

It is commonly acknowledged, that a decrease in the element dimension of the reinforcements, besides a durable mechanical connection at the crossing point, devoid of any existence in chemical reaction artifact, would lead to an enhancement in power. Benefits of in-situ MMCs are that they are highly consistent in their microstructure and thermodynamically high steady. Furthermore, they too ensure solid interfacial connection among the matrices and the reinforcements. Solicitations of in-situ amalgams comprise wear spares of jet mill nozzles, valves, pumps, gun barrel liners, heat exchangers, chute liners [13]. The integration of TiB_2 elements in the matrix by in-situ handling suggests distinct benefits, for instance, spotless matrix-particle connection ensuing in active load transmission and reducing wear rates [14].

Numerous approaches are engaged in the engineering of MMCs. Stir casting is taken as an appropriate standard technique, owing to its distinct characteristic features. In this technique, the reinforcing elements are divulged into a liquefied substance, and they are stirred meticulously for a homogeneous combination with the matrix amalgam. The characteristics of the particle reinforced metal matrix mixtures created are prejudiced to a great amount by the dimension, nature and weight fraction of the reinforcing elements and their dispersal in cast matrix [15]. Stir moulding permits the usage of primitive metal handling techniques by the accumulation of a suitable stirring scheme for instance, centrifugal potency stirring ; ultrasonic or electromagnetic stirring or machine-driven stirring [16].

Some researchers described the fabrication and characterization of aluminium amalgam metal matrix composites reinforced with TiB_2. Evidence associated with the fabrication of aluminium based amalgams reinforced with TiB_2 with different reaction holding times is, however very limited. The intention of this study is to investigate wear characteristics of the composite Al6061-TiB_2 created by the joint effects of stir casting and in-situ methods through dissimilar reaction holding periods, and to compare the wear characteristics using that of the matrix alloy Al6061.

EXPERIMENTAL PROCEDURE

Materials

- The matrix material for present study was Al6061. Table 1 gives the chemical composition of Al6061.

Table 1: **Chemical Characteristics of Al 6061**

Element	Mg	Si	Mn	Cu	Fe	Ti	V	Al
Mass %	1.04	0.62	0.53	0.31	0.19	0.04	0.02	Bal

- The reinforcement material was TiB_2, which was produced by adding the halide salts, potassium hexa flurotitanate (K_2TiF_6) and potassium tetra fluroborate (KBF_4) in the molten Al6061 alloy at 850 °C by in-situ method. The TiB_2 development happened because of chemical response of the halide salts to the liquefied aluminium alloy, as per the following reactions :

$$3K_2TiF_6+22Al+6KBF_4\rightarrow 3Al_3Ti+3AlB_2+9kAlF_4+K_3AlF_6+\text{ Heat} \quad (1)$$

$$3Al_3Ti+3AlB_2\rightarrow 12Al+3TiB_2 \quad (2)$$

Processing

By means of an electrical resistance furnace at a temperature of 850 ºC in a graphite crucible of 1 kg volume, Al 6061 alloy was liquefied. For homogenization of the temperature, the alloy was persisted with at this temperature for around 5 minutes, while it was stirred at 600 rpm by means of mild steel stirrer layered with zirconia. The two halide salts in proper amounts were hosted to melt and stirring was carried out continuously. Through diverse reaction holding periods in steps of 15 minutes to 60 minutes, the heat was sustained at 850ºC to examine the liaison among the degree of chemical response and the growth performance of the reinforcement phase. The cryolite slag was skimmed out meticulously by the close of every holding time, and by means of a mild steel vacuum cylindrical die layered with zirconia, the composite was casted into rods of 16 mm diameter. The compound mixture was designed by the constant dispersal of the reinforcement particles TiB_2 in the Al-6061 amalgam matrix phase by the pooled properties of stir casting and in-situ systems.

A pin-on-disc wear analysis machine, as shown in figure 1 was handled to learn the dry sliding wear characteristics of the composites. Figure 2 indicates the specimen of the matrix amalgam and the composite mixtures. The diameter and length of the pin conforms to ASTM G99 standard. The pin was 30 mm long with 8 mm diameter.

Figure 1: Pin-on-Disc Wear Analysing Machine

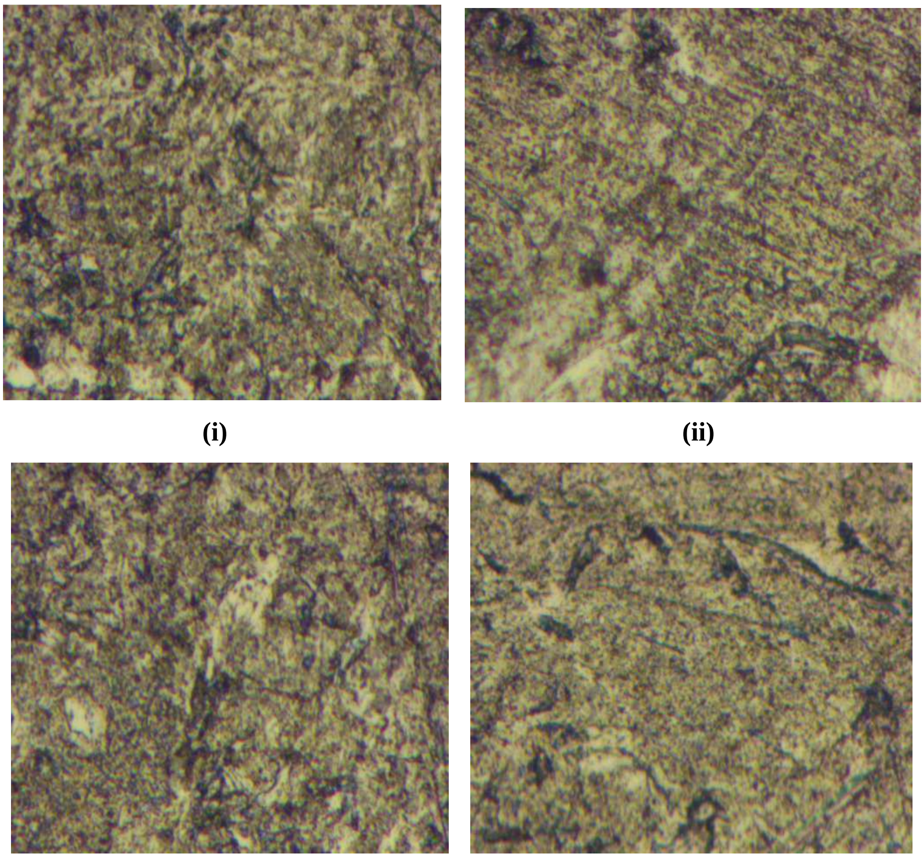
Figure 2: Wear Test Specimen

The alloy and composite elements were employed as test constituents for the pin. The test pins were weighed down with the dead weight in contradiction to the disc. To guarantee that the tests remained in minimal dry sliding situation, the pin and disc were splashed through acetone. In order to estimate the weight of the pin, a digital balance with an accuracy of 0.1mg was employed before and after every test. By the mass loss measurement, the wear rate was estimated. The experiments were carried out at different loads of 10, 20 and 30 N. The sliding speed as well as track breadth was secured to be 1000 rpm and 120 mm respectively, for 15 minutes of sliding time. The research analysis was performed at intermediate temperatures without lubrication.

RESULTS AND DISCUSSIONS

Microstructure

The features of the Metal Matrix Composites (MMCs) pivot not merely on the matrix, particle and the dimensional fraction, but similarly on the scattering of reinforcing elements and interface relationship amongst the particle as well as matrix. The photomicrographs of the mixtures reinforced with TiB_2 by in-situ method with dissimilar reaction holding periods have been exposed in Figures 3 (a) to (d), which indicate a uniform scattering of the reinforcement phase, TiB_2 in the matrix amalgam Al 6061 owed to the pooled properties of stir casting and in-situ methods, employed in the development of the composite.



(i) (ii) (iii) (iv)

Figure 3 (i): Metallographic Structure of Al6061-TiB_2 Compound in 15 Minutes' RHT (1000X)
(ii): Metallographic Structure of Al 6061-Tib_2Compoundin30 Minutes' RHT (1000X)
(iii): Metallographic Structure of Al 6061-Tib_2Compoundin 45 Minutes' RHT (1000X)
(iv): Metallographic Structure of Al 6061-Tib_2Compoundin 60 Minutes' RHT (1000X)

Wear Testing

At a continual speed of 1000 rpm for 15 minutes, tests of dry sliding wear were steered for every sample by means of a pin-on-disc wear analysing instrument to inspect the wear features of both the matrix amalgam Al 6061 and Al 6061-TiB_2 mixtures with diverse reaction holding times. The wear amounts of the matrix amalgam and various mixtures with dissimilar applied loads were attained as revealed in Table 2.

Wear Rate Calculation

A sample wear rate calculation for the base alloy, Al 6061for an applied load of 10 N for 15 minutes is as follows:

Volume loss (mm3) = Mass (g) / Density (g/mm3)

= 0.0102 / 0.0027 = 3.7778 (mm3)

Sliding distance = π x Dia of Disc(D) x Speed (N) x Time (t)

= πx 0.120 x 1000 x 15 = 5654.87 m

Wear Rate = Volume loss / sliding distance

= 3.7778 / 5654.87 = 0.000668 mm^3/N-m

Specific wear rate = Wear rate/Load = 0.000668/10 = 0.0000668 mm^3/N-m

Wear resistance = Sliding distance / Volume loss m/mm^3

= 5654.87/ 3.7778 = 1496.8685 m/mm3

Similarly, for other composites with different reaction holding times under various loading conditions, the volume losses, wear rates, specific wear ratesand wear resistances are calculated and tabulated in Table -2.

Table 2: Wear Results of Al6061and Al6061-TiB2 Composites with Different RHTs

Specimen	Load in (N)	Mass Loss in (gm)	Volume Loss in (mm^3)	Wear Rate x 10^{-4} in (mm^3/m)	Specific Wear Rate x 10^{-4} in (mm^3/N-m)	Wear Resistance in (m/mm^3)
Matrix Alloy Al 6061	10	0.0102	3.7778	6.681	0.6681	1496.869
	20	0.0198	7.3333	12.968	0.6484	771.122
	30	0.0296	10.963	19.387	0.6462	515.814
Composite with 15mts RHT	10	0.0070	2.5926	4.585	0.4585	2181.157
	20	0.0134	4.9627	8.776	0.4388	1139.474
	30	0.0196	7.2597	12.838	0.4279	778.939
Composite with 30mts RHT	10	0.0056	2.0742	3.668	0.3668	2726.289
	20	0.0107	3.9629	7.008	0.3504	1426.952
	30	0.0159	5.9122	10.455	0.3485	956.475
Composite with 45mts RHT	10	0.0061	2.2608	3.998	0.3998	2501.269
	20	0.0118	4.3780	7.742	0.3871	1291.656
	30	0.0166	6.1559	10.886	0.3628	918.609
Composite with 60mts RHT	10	0.0065	2.4074	4.2572	0.4257	2348.953
	20	0.0124	4.5926	8.1215	0.4061	1231.300
	30	0.0176	6.5348	11.556	0.3852	865.347

The table-2 displays the wear effects of matrix amalgam and portrays the four dissimilar composites takingdiverse reaction holding stretches. It is perceived that as the load rises, the rate of wear also intensifies in all circumstances. Since

at whatever time it is applied the load rises, the friction at the touching base surface of the substance and the rotating disc rises. This indicates an increase in wear rates. After the outcomes, it can be realised that the wear level of the unreinforced matrix amalgam is higher than that of the composites for entire applied loads. Wear level remained less for a least applied load. But, when the load was additionally amplified up to 30 N, the rate of wear in the matrix compound and the composites increased. Figure 4 represents the graph of Wear rate Vs applied load meant for both matrix amalgam Al 6061 and Al 6061- TiB_2 mixtures, with fluctuating Reaction Holding Times (RHTs) for a persistent speed of 1000 rpm and at a steady time of 15minutes.

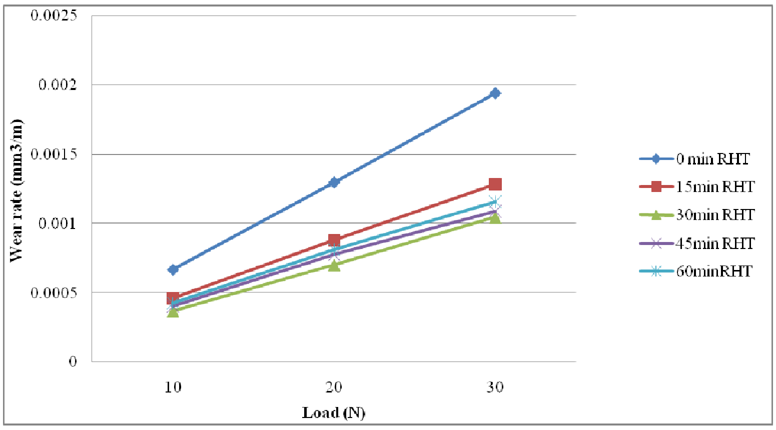


Figure 4: Graph of Wear Rate Vs Practical Load by Different Reaction Holding Times (RHTs)

The figure 5 illustrates the grid of Specimen sample with the wear rate of matrix mixture and its compounds with diverse reaction holding times. The wear rate declines by means of rise in the reaction holding period untill 30 minutes' reaction holding time, wheareas it increases by additional rise in reaction holding times further than 30 minutes.

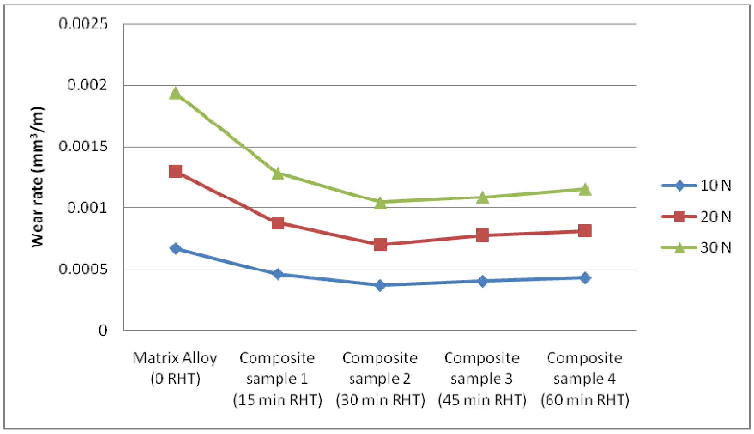


Figure 5: Graph of Specimen Vs Wear Rate of Matrix Alloy and its Composites with Different Reaction Holding Times

Figure 6 indicates the graph comparision of sample with wear resistance of the matrix amalgam Al 6061 and its mixtures. It can be seen that the composite 2 having 30 minutes' reaction holding time shows greater wear resistance compared with the other. The wear resistance of the Al 6061 matrix alloy and its amalgams rises with a rise in reaction holding time upto 30 minutes, and thereafter tends to decline. As a result of the existence of rigidreinforcementelements in the matrix material, the wear resistance of the composite material is enhanced.

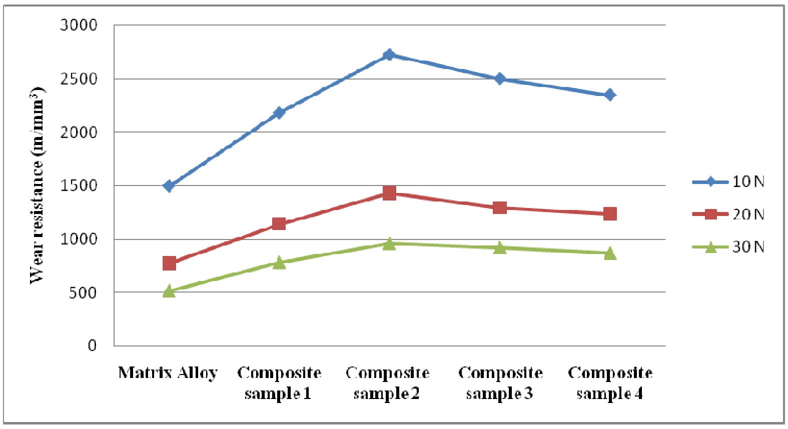


Figure 6: Specimen Vs Wear Resistance

When the reaction holding time is amplified auxiliaryby steps of 15 minutes' as of 30 to 60 minutes, there is a decline in the composite wear resistance. It is obvious that the wear resistance of the composite material is superior to that of matrix alloy Al 6061.

Figure 7 shows the graph, Specimen Vs Specific wear rate of the matrix alloy and the composites under different loads. Specific wear rate is least minimum for sample 2, having 30 minutes' reaction holding time for all applied loads.

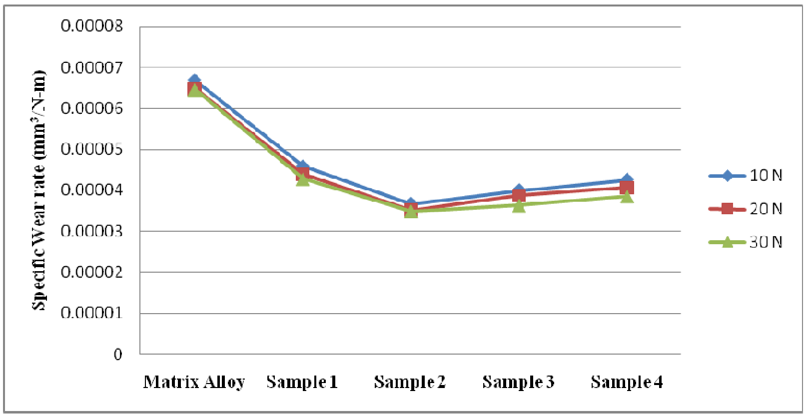


Figure 7: Specimen vs Specific Wear Rate of Matrix Alloy

With dissimilar reaction holding times, the photomicrogaphs of the worn surfaces of the composites were taken as shown in Figure 8 (a) to (d). From the photographs, it is clear that composite with 30 minutes' reaction holding time has less wear and more wear resistance compared to other composites. The homogeneous dissemination of the reinforcement elements are endowed for the enhanced wear resistance of the amalgam.

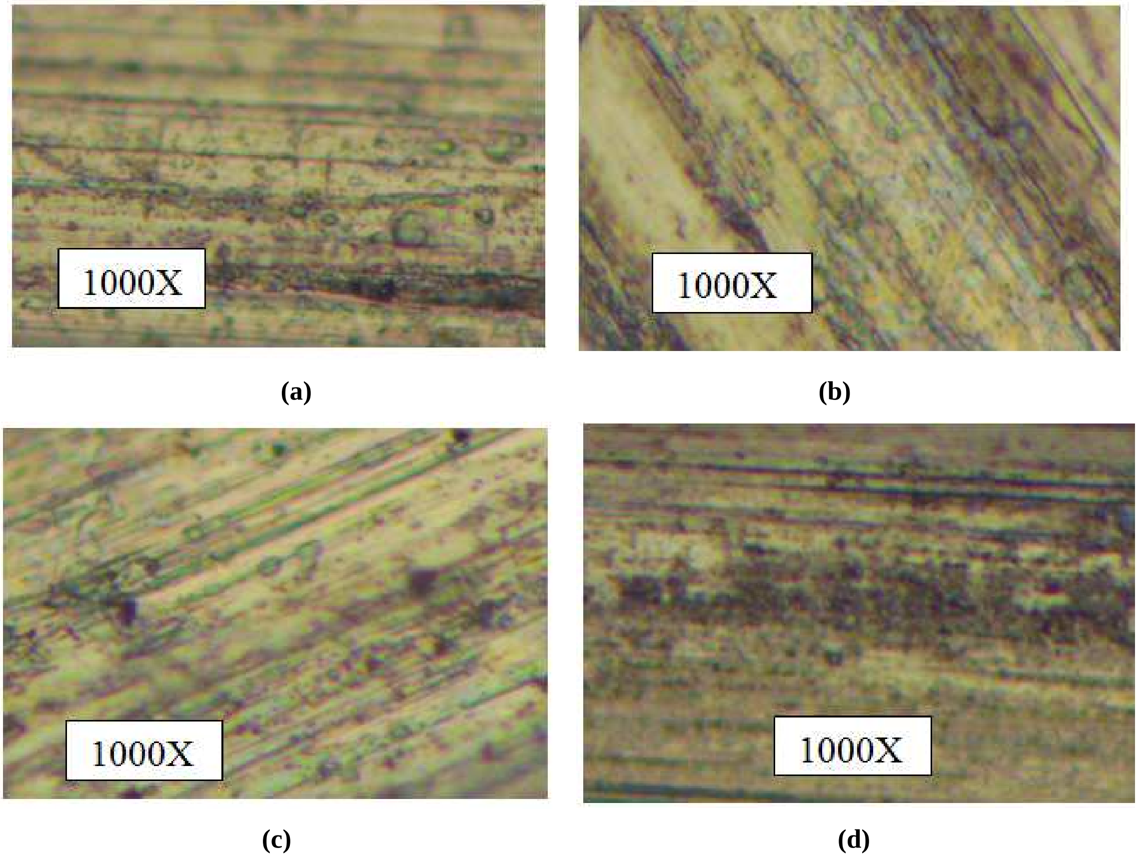


Figure 8: (a) to (d): Photomicrographs of Worn Surfaces of Composites with 15, 30, 45 and 60 Minutes' Reaction Holding Times

CONCLUSIONS

In the present investigation, by presenting halide salts K_2TiF_6 and KBF_4 into the matrix alloy Al 6061 at 850ºC and by the joined effects of the stircasting and in-situ methods, Al 6061- TiB_2 metal matrix composite was pursued efficiently. The microstructural analysis evidently discloses almost constant spreading of TiB_2 elements in the matrix material. With a rise in the functional load, the rate of wear of the matrix amalgam and the composites also rises. The integration of TiB_2 elements into the matrix substance improves the wear resistance, as correlated to the unreinforced matrix substance. From the results, it is found that the composite having 30 minutes' reaction holding time shows higher wear resistance and less wear rate compared with other composites. This may be due to the strengthening mechanism viz. the dispersion hardening of the matrix material. When the enforced load rises the wear rates of the two, the composite and the unreinforced matrix substance rises. By reaction holding time of 30 minutes, the photomicrographs of the worn faces of the amalgams indicate that there is a smaller amount of damage on the worn surface of the composite.

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